On Communicating the Value of Basic Physics Research to the Public

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Abstract

The Argument that basic scientific research is of value is a strong one, but may not be always communicated very well to the public. As a result, even though the public overwhelmingly supports science, it may not always support important basic physics research projects. This can have definite consequences on policy decisions, as happened when the superconducting supercollider was shut down after pouring 2 billion dollars into it. This article makes six recommendations, directed primarily at physicists, but also more generally applicable to all scientists, to help communicate the value of basic physics research to the public more effectively. Doing this is especially important now, as we find ourselves at a juncture at which the United States appears to be on the verge of abdicating its leadership role in many areas of science and technology.

Keywords: Value of Basic Science Research, Communicating Science, Public Outreach

1 Introduction

Scientific Research can be categorized in various ways, but the simplest way is to divide it into basic and applied research. This distinction, when considered in conjunction with development, is called the Linear Model of Research and Innovation [1] and reflects the fact that whereas applied research is frequently driven to solve a particular problem, basic research most often has as its goal satisfying a basic curiosity about an aspect of nature.

Of the possible types of basic research in science, that conducted in physics often seems both the most arcane and the most expensive. It is probably fair to say that the general public on the whole has very little knowledge of and concern for this type of research. As a consequence, even though Americans in general are overwhelmingly supportive of science [2], they may at times not be willing to support certain basic physics research projects, and this can have consequences on policy decisions that affect these kinds of projects. The clearest example of this occurred in the early 1990s when, after pouring over 2 billion dollars into the Superconducting Supercollider, a facility that would have tremendously advanced our fundamental understanding of nature, Congress decided to abort the project [3].

Given that the federal government funds a major portion of the national research and development, and that politicians often do listen to their constituents when making policy decisions, the influence of the public on scientific research should not be underestimated. The argument that basic physics research has definite value to society is very strong but it may well be that its value is often not communicated very well to the public. This article, after briefly discussing the scope and value of basic physics research, makes six recommendations for better communicating the value of basic physics research to the general public.

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2 The Scope and Value of Basic Physics Research

Let us briefly consider the scope basic physics research by means of a few examples, differentiated by cost, and the value this type of research provides. There is a definite association between fundamental physics research and 'big science'. A case in point is the Large Hadron Collider, a high-energy particle accelerator designed to test our most basic framework for the laws of nature, the standard model. With a radius of 27 km (18 miles), an expected cost of several billion dollars and the involvement of several thousand scientists, it epitomizes big science conducted in the service of investigating our most fundamental understanding of nature for its own sake [4]. The LHC, however, is by no means a lone giant. Other 'big science' basic physics research projects include the Hubble Space Telescope, designed to see into space at unprecedented level of resolution [5] , the National Ignition Facility (NIF), built to help achieve self-sustaining nuclear fusion [6] and the Laser Interferometer Gravitational Wave Observatory (LIGO), created to detect gravitational waves, a prediction of Einstein's theory of General Relativity [7].

Lest this gives the impression that basic physics research necessarily requires big budgets, it must be emphasized that there are also many relatively 'small science' projects which further our understanding of important fundamental aspects of nature. Some of the best-known examples of these are the double slit electron diffraction experiment, which demonstrated that electrons can behave like waves [8], the Pound-Rebka experiment, which verified the redshift of light emitted in a direction away from a gravitational field source [9], the experiments by Aspect et. al, which definitively established that non-local correlations between distant events predicted by quantum mechanics do occur in nature [10], and the experiments by Cornell and Wieman that synthesized a new state of matter predicted 70 years before by Bose and Einstein [11].

What is the value of these and other basic physics research projects? There are two very different kinds of answer. The first is that this type of research ennobles us, as it is part and parcel of the quintessentially human enterprise. Whereas almost all creatures are merely preoccupied with feeding, breeding and sleeping, we can at least sometimes lay claim to tending a higher-purpose need, namely, satisfying our curiosity and nurturing our sense of awe about nature. This has produced definite results: We are the only living beings on this planet that have something that comes close to a fundamental understanding of our existence and of our world. Our scientific discoveries have led us to realize that there are aspects of nature which our ancestors could never have imagined even in their wildest dreams. Attaining and formulating such understanding has to rank among the noblest activities alongside the creation of magnificent art, music and literature, and arguably nothing has had as much of an impact on attaining it than basic science and in particular fundamental physics research.

The second answer is pragmatic: if one considers historically the long-term practical value of basic physics research, it turns out that so far it has actually been *indispensable* for creating new practical technologies with direct societal benefits. To make this point clear, consider our most fundamental theories of nature: relativity and quantum mechanics. It was the special theory of relativity, an abstruse framework concerned with the behavior of rulers and clocks at high relative velocities, which established an equivalence between mass and energy. A little more than three decades later, this equivalence was used as a basis for nuclear fission experiments which led to the development of technology that harnesses nuclear energy[12]. Without the general theory of relativity, on the other hand, global positioning systems could not work properly, as they need to be reset periodically to take the effects of gravity on time measurements into account[13]. Quantum mechanics, our fundamental theory of nature at small scales in the non-relativistic limit, underlies much of our current technology: TVs, lasers, computers, transistors, and iPads would be unthinkable without quantum mechanics, a theory which currently lacks even a universally accepted interpretation, being, as it is, based on a set of highly abstract mathematical postulates [14].

More recently, the massive investment in fundamental physics research in the United States triggered by the launch of Sputnik in 1957 can be credited for many of the advantages in science and technology we enjoy today over other countries. Yet much of the public seems oblivious to that, apparently thinking that this is more the result of good fortune. Consequently, it may not support future investments in basic science research as much as is necessary to sustain new practical innovations in science and technology at the same level as before [3]. This suggests that if the value of fundamental science research in general and basic physics research in particular was communicated more effectively, then the public would be more supportive of it.

3 Communicating the Value of Basic Science Research more Effectively

This section will give six recommendations for communicating the value of basic science research more effectively to the general public. While primarily directed at physicists involved in fundamental research, practitioners in other areas of science may find these useful as well and for this reason, the terms physics and science will in this context often be used interchangeably. Many of these recommendations are undoubtedly what one would call "common sense", but it may help to be reminded of them every once in a while.

Treat public outreach as a Scientific Subject The manner in which a public outreach project is executed can greatly influence its effectiveness at conveying the value of basic research to the public. One way to enhance one's effectiveness as science communicator is to attempt to learn the methods of exposition of the masters (or at least draw inspiration from them) such as the late Richard Feynman, several of whose public lectures are freely available online [16][15]. Yet it is easy to forget that public outreach conducted by scientists can be treated as subject of scientific inquiry. In this context, the findings from physics education research (PER), itself a surprisingly young field, may help determine the most effective ways in which this value can be communicated. It turns out that there exist teaching strategies that are far superior to the standard lecture-based way of teaching physics in the classroom. These strategies transform the lecturer into a cognitive coach whose focus it is by means of interactive teaching methods to train students to engage in expert-like thinking: Whereas novices tend to see science as a large collection of isolated facts unrelated to the world and handed down by an authority, experts see a coherent structure of concepts that describes nature and was established by experiment [17]. Many of the detailed insights gained from PER may be applicable to occasions in which scientists attempt to convey an idea about their work or any other topics in science to the public. This is important because all too often popularizations may fall in one of two traps: Either they are so dumbed down that the explanations of scientific concept become mere caricatures, or else they are so sophisticated that all but those with the strongest physics background are unable to follow. It is therefore important to be able to tailor the message and the level of sophistication to the audience while still conveying scientific concepts reasonably accurately.

Yet another potential trap peculiar to fundamental physics is that scientific speculations may inadvertently be misrepresented as established facts. Of course physicists know well that there is a difference between relativity and quantum mechanics on the one side, and, say, string theory and loop quantum gravity on the other: whereas the former are theories universally accepted in the scientific community because they have withstood extensive experimental challenges, the latter are speculative extensions that have yet to await direct experimental tests. Often, however, the general public may not understand the fundamental difference between them and therefore come to believe that some of the highly speculative ideas entailed by the extensions, such as unseen extra dimensions, are treated by scientists as though they were facts of nature. That, besides conveying the wrong idea about science, such misrepresentation can have real negative consequences on scientific research is illustrated by the following example: just prior to commencing the operation of the LHC, there was a widespread latent fear that it might lead to the formation of miniature black holes that would eventually destroy the earth, and these fears even led to an unsuccessful lawsuit to prevent the LHC from operating [18].

Taking a scientific approach to the popularization of science may help scientists avoid these traps and increase the effectiveness of their efforts. It may even reveal, as in the case of the PER findings, that novel communication strategies are superior to cherished traditional methods.

Consider Communication with the public an integral part of your work as a scientist In this age of information, there are more ways than ever for individuals to share aspects of their lives with the public. Weblogs, Facebook, Twitter and a host of other social media have essentially removed many of the obstacles that previous generations of scientists faced when they wanted to share their work and their views with the world. Some scientists have already taken advantage of these as there exist, for example, science blogs which fulfill an important function in communicating with the public, such as it pertains to better explaining new scientific discoveries or clarifying common scientific misconceptions and so on.

There is, however, room to do a lot more. Often the public is most interested in the work and the perspective of the most accomplished practitioners of science. When the communication between scientists who are the leaders in their fields and the public is examined, it is unfortunately often found to be rather lacking. For example, of the living physics Nobel laureates, only a handful appear to engage consistently in any sort of publicly visible outreach. Nobel Laureates, having been publicly recognized for their important contributions, are among the best-positioned physicists to communicate the value of basic physics research. They carry the authority that compels people of all backgrounds to listen to them. If they do not see it as their responsibility to communicate the value of scientific research to the public now, it is likely because they never saw it as their responsibility. That implies a more general cultural predisposition of scientists to focus exclusively on communicating with their peers, leaving concern for public understanding of their work as a matter of secondary importance, if it is a concern at all.

Indeed, to the extent that public outreach is perceived as distraction from research, it may be regarded as a liability. For instance, an eminent scientist nearly withdrew from a speaking engagement when he found out that another feature speaker at the event was Carl Sagan [19].

A science culture which fosters this sort of attitude toward public outreach seems inconsistent with the wish of scientists for the public to make the financial support of their work a priority. A change in this attitude would probably most effectively come from the top: If more of the leading scientists were to regard communicating with the public as an important part of their work, then this would most rapidly lead to a change in this cultural norm. However, this does not mean that individual scientists cannot help bring about such a change. The fact that virtually all major science magazines by now feature blogs by scientists may offer a glimmer of hope that perhaps one day "science communicator to the public" will become part of the professional identity of every scientist.

Involve the public more systematically in your scientific endeavors There is a secret that at least some organizations, especially not-for-profit ones, have discovered: when your customers, donors or benefactors become more directly involved in your work, their commitment to your cause increases. While the public is ultimately paying for much of basic science research, it is generally not otherwise deeply involved. However, there are some projects that have found creative ways through which the lay public can meaningfully contribute to basic research. For instance, the distributed computing projects Einstein@home and SETI@home use the aggregate processing power of up to millions of individual personal computers to analyze the gigantic amounts of data generated by observatories [20]][21]; For the last hundred years, amateur astronomers have collaborated with professional astronomers in variable star observations, also sometimes discovering comets or other transient objects [22]; an online video puzzle game called Foldit allows players to collaborate with scientists to predict the structure of certain protein molecules and has in fact already led to the discovery of the structure of a retrovirus enzyme which may open the door to novel therapies for the human immunodeficiency virus [23].

These examples demonstrate how the public can be involved more closely in the work of scientists, and those who are engaged with science in this way are likely among its strongest supporters within the lay public. The challenge is to think of even more new creative ways to extend this kind of collaboration, so that rather than being the exception, it becomes the rule that governs the relation between society and science. A society in which this kind of interaction between scientists and public citizens is the norm, a society that in this sense is made out of citizen-scientists, is one that is far more likely to be supportive of scientific endeavors.

Some of the resources that the public can bring to the table are time, computer processing power, the ability to perform simple tasks in a general setting, the ability to perform complex tasks in a specialized game setting or when the tasks coincide with those familiar from vocational or personal experience, the ability to observe, record and report observations, and the ability to provide feedback on or evaluate an observation or experience.

The more scientists can come up with similar creative collaborations, the more they will find that this not only represents a huge untapped resource that can directly support their work, but that it also helps instill the value of scientific research in the public. Ideally, it should become an integral part of the formulation of any new basic scientific research project to ask in what ways these kinds of public resources can be used to support that project. Of course, not every project is suitable, but if such collaborations are considered as a matter of course, they may uncover possibilities we have not even imagined yet. The systematic inclusion of the public in scientific work in this way is an indirect way of communicating the value of basic scientific research to the public, but nonetheless it may be among the most effective

Collaborate with others to create a mechanism through which the public outreach resources of one community can be matched to the needs of another Public engagement efforts by scientists usually occur most vigorously in communities with a high concentration of research activity. For instance, the University of Michigan department of physics began a Saturday morning physics program in 1995 which has regularly brought in several hundreds of lay people to each lecture since the very beginning [24]. Yet the greatest need for these types of programs may lie in other communities, particularly ones with a smaller concentration of scientists.

A mechanism through which abundant outreach resources in one community can be channeled to the outreach needs of another would greatly extend the effectiveness of existing resources. The recommendation here is not for a specific kind of model but rather for considering a variety of possibilities which may satisfy the constraints on such a mechanism in particular situations.

For example, one model might be a speaker's bureau for scientists who are willing to talk to the public. Indeed the American Physics Society has a physics education speaker bureau, but this contains only 29 members for the entire United States [25], and the cost of inviting a speaker may be prohibitive for many venues. Another model might be the establishment of regular meetings similar in format to the science cafe model [26] or within the framework of a science open house, perhaps even coupled with the possibility of online interactions that can lead to the formation of an online community, such as occurs under the meetup.com model[27].

Whatever the model, it is clear that establishing this type of mechanism on a national scale requires the co-operation of scientists, their employers, funding agencies, professional organizations, outlets through which the public outreach functions can be performed (such as local schools) and local community organizers. Of the recommendations given in this article, this may be the one that can be most realistically implemented through policy channels. For instance, funding agencies could directly set some funds aside to help establish the mechanism directly or otherwise indirectly set the stage so that interested not-for profit organizations or entrepreneurs with an interest in the promotion and popularization of science can more easily take on the role of implementing particular models.

How could the development of such a network make a definite difference? Here is an example: In late 2011, the Texas Higher Education Coordinating Board announced that it would shut down nearly half of the undergraduate physics programs at Texas public universities within a couple years if they continued to be "low performing" i.e. have a very low number of physics majors. Although it is matter of speculation, one can imagine that had well-attended outreach programs similar to Michigan's Saturday Morning physics programs existed at these schools, there would be a strong negative public reaction to these announcements on which the schools could rely for support. Furthermore, as these kinds of events may be visited by high school or middle school students (for instance, to perform science class assignments), to the extent that they foster further interest and the aspiration to study physics, such events might in effect serve as creators of a pool of potential future physics majors. Thus, in this instance, the communication of the value of basic research to the public might actually help the very survival of these departments. Of course, since they are so small, they may not have the resources to organize such events by themselves, but that precisely highlights the need for a mechanism by which public outreach resources can be directed from places where they are abundant to places where they are needed most. Similarly drastic measures as in Texas are already being considered in several other states [28], so beyond helping to utilize existing public outreach resources more effectively, such a mechanism could also help address a more acute need in these areas.

Engage the public from an early age on It is a simple fact of life that by the time we reach adulthood, most of us become in many ways set in our ways. Some fields and industries have cleverly taken advantage of this: When passion for, say, baseball is instilled in a child at a young age, the stage is set for the addition of one more lifelong baseball fan.

The earlier children are involved with science, the more likely they come to develop a lifelong appreciation for it. Indeed, children are naturally well-suited as an audience for communicating the essence of science and scientific research because they still retain all the curiosity about the world that is often so hard to find in adults, and because they may not yet have developed preconceived notions such as the idea that science is for nerds or "uncool". If an excitement and a passion for science can be cultivated in children early on, then the potential benefits are manifold: Once these children grow up, they may feel the desire to study the sciences and pursue a career therein. Even if they don't they might still be inclined to support the sciences in meaningful ways, either financially or politically and be better equipped to critically evaluate pseudoscientific ideas, such as intelligent design. Most importantly, they would feel compelled to share their passion with their own children, thus perpetuating a lifelong an appreciation for science across generations, much as it now often occurs for the sports.

Avoid arrogance when interacting with the public Science is a subject of study that requires a great amount of sustained effort over a very long period of time to master, and especially so for physics. It frankly takes a lot of hard work and training to become a physicist. As a result, physicists are often much better equipped than laymen to recognize the many dimensions and implications of a particular argument that applies in their area of expertise. This may foster a low regard for the views of others who are not experts, and sometimes lead to a premature dismissal of non-expert perspectives on a particular scientific issue as naïve and uninformed. This is probably exacerbated in the area of fundamental physics because while the subject matter tends to be very far removed from the realm of our every day experiences there is a subset of the general population which does have a strong interest in this field and sometimes even feels the need to contribute. A rather common example of this occurs when an article not published in a scientific journal or an argument presented outside formal scientific channels is given no credence without actually examining its content. To be fair, most physicists are not arrogant but do tend to be very busy, and what may be simply an attempt at better time management may be construed as arrogance. Nevertheless, to the extent that this fosters an image of scientists who are too conceited to come out of their ivory towers to tell the unwashed masses what it is that they are actually doing, it may contribute to a negative perception of scientists.
Sometimes the display of arrogance can be subtle. A theoretical physicist who waxes poetic about the beauty of the mathematics of a theory without effectively conveying this beauty to his audience may well be conveying instead the impression that he is stroking his ego ("This beauty can only be appreciated by a few exalted minds, and one of them is mine"). Ultimately, this hurts the image of physicists and of scientists in general: It widens the gap between them and a public that may already find it difficult to relate to them and reinforces the unfortunate stereotypical image, propagated in much of pop culture, of the 'mad scientist' who is utterly oblivious to the concerns and needs of the rest of the world.
In the end, the admonishment to avoid arrogance amounts to a call for empathy for the average public citizen for whom fundamental physics is way over the head. Imagine that your hard-earned tax dollars were going to a community of people whose activity was largely unintelligible to you, who did not value your views, and whose activity had no immediately discernible benefits to anything you might directly care about. Would you be inclined to continue to support this community financially?

4 Conclusion

After providing a brief discussion on the scope and the value of basic physics research, this article attempted to present some recommendations meant to help scientists in general and physicists in particular to communicate the value of basic research to the public. Effectively communicating the value of basic scientific and in particular physics research is particularly important now, as we find ourselves at a juncture at which the United States appears to be on the verge of abdicating its leadership role in several areas of science and technology. Even if some of these recommendations may seem difficult to implement, they should at least be tested in selected areas and its outcomes studied so that they can be refined into more empirically grounded recommendations.

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